

Localized Nucleation and Growth of Pb clusters on n-Si(111):H surfaces

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Metal clusters with widths of a few nanometers have been electrochemically deposited onto foreign metal substrates by several groups using scanning probe microscope (SPM) techniques [1-5]. However, in view of electronic applications, metal nanostructures are required to be deposited onto semiconducting or isolating substrates.

The major problem, which arises during electrochemical nanostructuring of semiconducting, e.g. silicon, surfaces is to image the deposited metal nanostructure. A potential difference of several hundred mV between tip and substrate, which is necessary for imaging silicon surfaces with STM in an electrochemical environment, and usually applied tunneling currents in the range of 0.5 - 2 nA result in a dissolution of previously deposited metal [6]. Nevertheless, very few groups have achieved a local deposition of metal clusters on silicon surfaces [7,8].

In this paper, we report on the successful, solely electrochemical and localized deposition of zero dimensional (0D) Pb clusters on n-Si(111):H substrates.

This has been achieved by applying a recently developed procedure, which allows the electrochemical growth of metal clusters on foreign substrates, and which avoids any mechanical or electrical contact between tip and substrate during the deposition routine [9]. The cluster formation can be exactly controlled allowing the creation of well-defined nanostructures [9].

Phosphorus doped n-Si(111) substrates have been cleaned by the conventional RCA method [10]. Subsequently, the substrates have been immersed for 1 min in 40% HF. High quality surfaces showing large atomically flat terraces have been obtained by a final preparation in „oxygen free“ NH_4F [11]. The electrolyte, 0.1 M HClO_4 / 1 mM $\text{Pb}(\text{ClO}_4)_2$, was deaerated before each experiment; the electrochemical cell was placed in a nitrogen ambient atmosphere during the experiments. All measurements were taken „in the dark“. A special STM tip preparation routine to form clean tip surfaces was applied. The tunneling currents during STM imaging were below 100 pA in order to avoid tip interaction with the Si surface or the deposited metal clusters.

Upon optimization of the deposition parameters, Pb clusters with lateral widths of less than 30 nm could be grown on the n-Si(111):H surface underneath the STM tip. Cluster movement or dissolution, which have been reported in the literature to be caused by the STM tip during imaging [6], have been found to be negligible for a period of at least 2 hours. A lateral adjustment of the STM tip position before the cluster deposition procedure allowed the electrodeposition of clusters either on atomically flat terraces or at step edges. Pb clusters deposited at n-Si(111):H atomic step edges have been observed to be more stable than clusters deposited on atomically flat terraces. As expected, an increase of the substrate potential above the 0D Pb/Pb^{2+} equilibrium potential accelerated the dissolution of the Pb clusters. This behaviour of 0D Pb clusters agrees with the recently published concept of the stability of low-dimensional systems [12].

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